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OBSERVATIONS ON *MARASMIUS OREADES* AND *CLITOCYBE GIGANTEA*, AS PARASITIC FUNGI CAUSING "FAIRY RINGS."

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With Plates V, VI, and VII, and 7 Text Figures.

Contents.

I.—Introduction.

During the last three years I have been watching the growth and gradual extension of numerous "fairy rings." All these rings have been formed by the fungus *Marasmius oreades*, with the exception of two particularly large ones, which are due to the fungus *Clitocybe gigantea*. I have taken measurements and made records of the annual extension of some of the *Marasmius oreades* rings, since they

are in a field which is not used for grazing purposes, but I have not been able to do the same with those formed by *Clitocybe gigantea*, because any stakes used to mark boundaries always disappeared—no doubt trodden down by cattle.

"Fairy rings" have been noted from very early times, and have more often been the subject of rhyme and romance than of scientific investigation.

In the *Wild Garland*, by S. Waring (1837), the death of the grass was said to be due to the spawn of the fungus enveloping the roots so closely that absorption was prevented.

In 1846 Way[1] suggested that the zone of luxuriant grass was due to the valuable manuring of phosphoric acid, potash and sulphate of lime left by the fungus of the previous year, and he considered that the fungus might still grow on that same zone were it not for competition with the now vigorous grass.

In 1875 Gilbert[2] published a paper "On the Occurrence of Fairy Rings," and in 1883 Lawes, Gilbert and Warrington[2] published a paper entitled "Contribution to the Chemistry of Fairy Rings."

These gave the results of an investigation which was undertaken to determine the source of the nitrogen of the "Fairy Ring" fungi, which evidently were the cause of a natural rotation of crops. It was concluded that the source of the nitrogen was the organic nitrogen of the soil itself.

In 1898, in Australia, McAlpine[3] published a paper "On Fairy Rings and the Fairy Ring Puff-Ball." He gave a brief account of the "Fairy Rings" caused by a puff-ball, *Lycoperdon cyclicum*, and was successful in exterminating them by means of the application of a 10 per cent. solution of sulphate of iron, and also by means of a Bordeaux mixture (Copper sulphate 6 lbs., quick lime 4 lbs., and water 25 gallons).

In 1905 Fr. Thomas[4] published the results of his observations on the growth of a fairy ring caused by *Hydnum suaveolens*. He found the average yearly increase was about 22 cms., and from that calculated that the ring must have been 45 years old.

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[1] Way. On the Fairy Rings of Pastures illustrating the use of Inorganic Manures. Chem. Sect. Brit. Assoc., 1846.

[2] J. H. Gilbert. Note on the Occurrence of "Fairy Rings," 1875. Sir J. B. Lawes, J. H. Gilbert, and R. Warrington. Contribution to the Chemistry of "Fairy Rings," 1883. Rothamsted Memoirs, vol. v.

[3] D. McAlpine. Report on Fairy Rings, and the Fairy Ring Puff Ball. Dept. of Agric., Victoria, 1898.

[4] Fr. Thomas. Die Wachstumsgeschwindigkeit eines Pilzkreises von *Hydnum suaveolens*. Scop. Ber. d. deutscher Bot., Ges., 1905, Bd. 23, p. 476.

In 1910 Massart[1] published a paper on "Fairy Rings," a summary of which was given in the *Journal of the Royal Microscopical Society*.

In this the sterility, as regards fungus growth of the ground enclosed by the ring, was noted, and also the fact that no fungi grew at the point of contact of two rings. From analogy with higher plants he argued that probably the mycelium secreted some poison fatal to further fungal growth, though not to the growth of higher plants.

From this review of the literature on the subject it will be seen that comparatively little is known about it. A satisfactory explanation as to why a "Fairy Ring" extends as a ring and not as a disc is still required; as yet no one knows how the fungus first infects the soil, and there appears to be only one good record of the yearly increase in radius of a ring. The rings caused by *Marasmius oreades* have received most attention from other workers, but hitherto the life-history of the fungus does not seem to have been worked out nor the problem of parasitism involved sufficiently investigated.

"Fairy Rings" often continue to extend for many years, possibly in some cases for fifty or even a hundred years. Sometimes they disappear unexpectedly and thus put an end to observations on yearly extension. Sometimes, too, segments of rings, after disappearing for a year or eighteen months, reappear again. It is obvious, therefore, that an investigation upon "Fairy Rings" must of necessity be incomplete unless extended over a long period of years.

II.—"FAIRY RINGS" FORMED BY MARASMIUS OREADES.

Observations were first made in the middle of June, 1908; the rings were then very conspicuous because of the dead grass on them (fig. A *b*), and because of the zone of rich dark green grass just within the ring of dead grass (fig. A *a*). These two zones have always been commented upon whenever fairy rings have been under discussion, but outside the ring of dead grass another ring (fig. A *c*) of dark green grass can invariably be seen also showing more vigorous growth than that of the field generally. This band is at first only an inch or so in width, but as the summer advances it extends, and towards the end of September it is broader than either the inner ring of dark green grass or the ring of dead grass. This

[1] Massart. Ann. Jard. Bot. Buitenzog. supp. 3, pt. 2, 1910, pp. 583-6; also J. R. M. S., 1910, p. 749

outer ring of dark green grass has perhaps hitherto escaped notice because, by the time it attains a width of several inches, the grass of the field generally with advancing summer and autumn has also

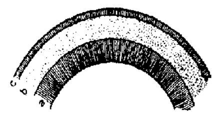


Fig. A.—Diagram showing the different zones of a "Fairy Ring."
a. Inner dark green grass zone. *b*. Dead grass zone.
c. Outer dark green grass zone.

deepened in colour, and does not present the contrast noticeable in connection with the luxuriant inner dark green band in spring and early summer.

The soil underneath these three zones, when examined, was found to be well penetrated by mycelium to a depth of about a foot, and under the ring of dead grass this was especially noticeable, since dense wefts of fungus hyphae among particles of soil could easily be discerned by the naked eye (Pl. v, fig. 5). In sods from nearer the centre of the ring than the inner dark green band of grass, there is no trace of fungus mycelium, other than that which is to be found in soil taken at random from any part of the field, for it is impossible to find turf quite free from fungus hyphae. The grasses killed by the fungus include *Holcus lanatus, Anthoxanthum odoratum, Agrostis stolonifer, Avena flavescens, Lolium perenne, Poa pratensis, Dactylus glomerata,* and with these were *Trifolium repens* and *Plantago lanceolata.*

During late summer and autumn the dead grass of the middle ring (fig. A *b*) is gradually replaced by dark green grass similar to that on the inner (fig. A *a*) and outer zones (fig. A *c*). This apparent revival is due to rhizomes from neighbouring living grass plants, for all rhizomes and roots connected with the surface dead grass are quite killed by the fungus and become thoroughly rotten. This also applies to the plaintain and clover associated with the grass, but docks and sorrels seem able to withstand the fungus.

During December, January and February, these fairy rings are hardly visible, but the soil contains just as much mycelium as at any other time of the year, only with this difference—the mycelium in the outer dark green grass zone has increased very much in quantity; here it has become so dense that it forms a white felt-work

which is very readily seen at the surface of the ground round the bases of the living grass shoots, and when plucked away looks like fragments of cotton wool.[1] About February or March, or later if the season is not mild, the grass on this zone begins to flag and finally dies, and what was the outer dark green grass zone of one year becomes the dead grass ring of the succeeding year.[2]

The dense white weft of mycelium on the surface remains visible for several months in fields of mowing grass, but it always disappears in summer in grazed fields or on lawns, no doubt because of the dry atmosphere to which it is subjected under exposed conditions. If the weather is mild and damp, about a month after the dying down of the

Fig. B.—A sod from a *Marasmius oreades* ring showing the fungi springing up on the dead grass zone. $\times \frac{1}{3}$.

grass, the sporophores of the fungus begin to appear and these are always most numerous were the surface mycelial weft is densest.

I.—The Influence of the Mycelium on the absorption of Water by the Soil.

A very striking feature in connection with Fairy Rings is the influence the fungus mycelium has on the absorption of water by the soil. The earliest notice of this known to the author is in a small

[1] This mycelium when pressed against litmus paper has an acid reaction.

[2] This year (1911) the grass on one ring was dead in January; this was probably due to the very mild weather during December favouring the growth of the fungus.

unscientific publication, called *The Wild Garland*, by S. Waring, 1837.

Gilbert and Lawes[1] also drew attention to this fact. They pointed out that under the dead grass zone (fig. A *b*) the soil was very dry and could only be wetted with difficulty. This is characteristic of both the *Marasmius oreades* and *Clitocybe gigantea* rings. The soil under the dead grass, even after continuous rain for a week or more, is always drier and paler in colour than that of the field generally; the soil under the inner and outer dark green grass zones (figs. A and C) is also always considerably drier than that well without or well within the ring, but it is not quite so impervious to moisture as the soil under the middle dead grass band (fig. A *b*).

Often in summer, after continuous rain for two or three days, sods from the dead grass zone, when examined, have been found to be quite pale in colour and only slightly damp compared with the saturated sods from well outside the ring; and after heavy rain, lasting nearly twenty-four hours, the moisture has not even penetrated the surface, whereas the soil at a distance of two feet either way has been damp to a depth of four inches or more.

This rendering of the substratum impervious to moisture seems not an uncommon characteristic of fungi. Falck[2] notes a similar phenomenon in connection with *Coprinus stercorarius*, and it is a matter of common observation that blotting paper grown over with *Mucor* can only with difficulty be wetted. Infected soil, even after sterilization, still offers resistance to the percolation of water.

In order to find some explanation of this phenomenon a series of experiments were made in which the rate of flow of water through infected and uninfected soil was tested in tree-pots. The pots held 60 cc. of soil.

In the first experiment a potful of ordinary uninfected soil was placed in each of three saucers; over the first was poured an extract, made by pounding up an equal quantity of infected soil with sufficient water to just cover it and leaving for twenty-four hours before straining; over the second saucer was poured an equal quantity of tap water; both lots of soil were well stirred up and made into a thick paste; the third lot was left untouched. These three lots of soil were left for two days to dry at a temperature of 40° C, after which the soil of each lot was pounded up in a mortar and replaced in a pot: equal quantities of water (7 cc. at a time) were then poured over the

[1] Gilbert and Lawes. *l. c.*

[2] Falck. Beitr. z. Biol. d. Pflanzen., 1902, Bd. viii. Die Cultur des Oidien und ihre Rückführung in die höhere Fruchtform bei den Basidiomycetes.

three pots simultaneously, and the time taken by the water to soak into the soil was noted. In each case the first 14 cc. of water sank rapidly, taking one and a half minutes to soak in, but afterwards the water took from a half to six minutes longer to soak into the soil which had been treated with soil extract or with water. This experiment was repeated three times with similar results.

It is known that solutions of organic matter, especially those which have little oil in them, have a surface tension below that of water[1]; hence it might perhaps have been inferred that the water of infected soil, since it undoubtedly contains some organic matter (enzymes, etc.) in solution, had a surface tension appreciably lower than that of soil-water generally. If this were so, less water would be raised from the subsoil, and water would percolate only slowly from the surface during rain, and in consequence infected soil would be drier than uninfected soil. But the above experiment seems to prove that the amount of organic matter in solution in infected soil is insufficient to lower the surface tension to a degree which would account for its dryness out in the field.

The following experiment has led to the conclusion that the dryness of the infected soil is due to the air entangled in the meshes of mycelium. Pots of infected and uninfected soil which had been made as damp as possible by pouring water over them, were placed in beakers which nearly fitted them, and the very narrow space (a few millimetres only) between the beaker and the pot was filled with water. These beakers containing the pots were placed in a water bath and boiled in order to drive all the air out of the soil and render it thoroughly water-logged. After boiling for one and a half hours the pots were taken out of the beakers, and the contents of the beakers were poured over the soil in the pots; when this had drained away the pots were watered simultaneously with equal quantities of water, and no difference was observed between the rate of flow through infected and uninfected soil.

Since the rate of flow of water through infected soil which has merely been subjected to steam in a steam sterilizer for three hours is still very slow compared with the rate through uninfected soil, sterilization, unlike actual boiling in water, evidently does not displace all the air which is entangled in the meshes of the mycelium; hence it may be concluded that the resistance infected soil offers to the passage of water through it, is due to the air entangled within the meshes of the mycelial network occupying the spaces between the particles of soil.

[1] A. D. Hall. The Soil, 1904, p. 78.

2.—MEASUREMENTS.

The following table gives measurements of the annual extension of three rings during four successive years, but it shows little save the fact that the rings increase in width and diameter annually.

RADIAL INCREASE ALONG SEVERAL DIFFERENT RADII.

	RADIUS OF RING	RADIAL INCREASE ALONG SEVERAL DIFFERENT RADII.			
	1907.	1908.	1909.	1910.	1911.
Ring A.	2 ft. 7½ inches	6 inches 6 ,,	7 inches 9 ,,	This ring had disappeared except one patch 14 inches in diameter.	The patch had become a disc 26½ inches in diameter.
Ring B.	4 ft. 4½ inches	6 inches	9½ inches	10½ inches	13½ inches.
		1 ,, 6 ,,	9 ,, 7½ ,,	9¼ ,, 13 ,,	Was not visible; near is a well manured tree, planted 1909.
		3 ,,	was not visible	10½ ,,	13½ inches.
Ring C. Part of a ring only.			6 inches 7 ,, 5 ,,	9 inches. 11 ,, 11 ,,	13½ inches. 13 ,, 13 ,,

The inner dark green grass zone does not always coincide with the dead grass zone of the previous year. It may also cover part of that of the year before; hence the effect of the fungus may even last three years. Also the whole of the dead grass zone does not always recover within one year and become covered by dark green grass; this year, 1911, in which the spring and early summer were very dry, in ring C the dead grass zone of last year was still visible to some extent and was separated from this year's zone of dead grass by a zone of living grass six inches wide. From the fourth measurement of ring B it will be seen that it is quite possible for the mycelium to grow outwards, and only occasionally be present in the soil in sufficient quantity to kill the grass. Other instances besides this have been observed; so that frequently the dead grass zone of one year is separated from that of a following year by an inch or two of grass which has never died down.

3.—The Colour of the Grass.

The grass of most pasture fields is not of a uniform green colour, but lighter and darker green patches give a mottled effect. Sods from many dark green patches taken from fields known to be free from "Fairy Rings" were examined with the idea that perhaps the richness of some of the grass might be due to mycelium being more abundant in those areas; but such is not the case. A little mycelium is nearly always present, but no more than is to be found in turf generally; and in the autumn, when fungus sporophores are plentiful in pastures, these are just as frequently found on the lighter as on the darker patches of turf. Nevertheless, the presence of fungus mycelium in turf seems associated in many instances with a darker green colour of the grass, even when it apparently does no harm, as in the case of *Tricholoma personatum* and others.

This dark colour of the grass may perhaps be correlated with the presence of ammonia in some combined form in the soil, for it is well known that many fungi produce ammonia as the result of their metabolic activity. Some experiments by Hutchinson and Millar[1] have shown that the percentages of nitrogen in the mixed herbage from the Rothamsted grass plots were greater when the manure used was mixed with ammonium salt or even consisted of ammonium salt alone, than when sodium nitrate was used, and the grass containing the higher percentage of nitrogen was a darker green.

4.—The Relation of the Fungus to the Grass.

The connection between the fungus and the grass is best seen by studying the grass plants on the outer edge of the outer dark green grass zone. Here the first attack of the fungus on the grass plant can be readily observed. The presence of the fungus mycelium among the roots is indicated by a brownish discolouration of the delicate root tips or of the external cortical tissue of the root just above this region, and by loss of symmetry of the root-hairs (Pl. v, fig. 6).

At this stage very few hyphae are present, and these are only loosely applied to the roots, but with an increase of mycelium the discolouration becomes more pronounced, and at the same time the root-hairs and young tissue are seen well invested and freely penetrated by hyphae. One or more hyphae can be seen traversing the length of a root-hair (Pl. v, fig. 6).

[1] H. B. Hutchinson and N. H. J. Millar. Jour. of Agri. Science, 1909, vol. iii, pt. 2. Direct assimilation of ammonium salts by plants.

If grass plants be taken from an infected area during January or February and be compared with those from an uninfected area, no difference between them will be apparent except at the roots; if these are washed free from soil the rusty colour of the infected roots will readily distinguish them from the pale healthy uninfected roots. The roots of infected plants also have a tendency to branch more than uninfected ones, and the root-tips, instead of having the usual slender tapering form, are frequently stunted. The rusty colour of infected roots is due to the great mass of dead and dying rootlets and rhizomes. The fungus penetrates and entirely consumes the soft parenchymatous parts of these structures and leaves untouched the tough axial stele, though this in time becomes rotten, and can be crumbled between the fingers, micro-organisms having no doubt continued the destructive work of the fungus (Pl. vi, figs. 11 and 12). The fungus finally enters the grass leaves, but not until they are almost dead; it is difficult to find any fungus in merely flagging leaves, though the leaf-sheaths of these show hyphae everywhere except in the vascular bundles (Pl. v, fig. 7). When the leaves are dead, mycelium abounds in all the tissues except the vascular bundles. Dead grass leaves from plants entirely unconnected with Fairy Rings always have fungus hyphae in them, but the mycelium belonging to *Marasmius oreades* cannot very well be mistaken for that normally found in such leaves, since the hyphae seen in the latter are generally of much larger diameter and usually fewer in number.

5.—Experiments on Grass Roots, with an Extract of Infected Soil.

From experiments made to see the influence of a water-extract of infected soil on normal grass roots, it appears that the fungus excretes some substance which has a fatal action on root-tips. In these experiments soil taken from below a dead grass zone was well stirred up with water to the consistency of a thin paste, and the roots of an uninfected grass plant were left in this for twenty-four hours. A similar experiment was arranged, but the mixture was boiled before the roots were placed in the liquid, and a third experiment using ordinary uninfected soil was kept as a control. To each extract a few drops of toluol was added as an antiseptic. These experiments were repeated many times, and always most of the root-tips which had remained for twenty-four hours in the extract of infected soil[1] turned brown or black (Pl. vi, fig. 13); the effect was

[1] The extract of infected soil is neutral to litmus paper, whereas the extract of uninfected soil is faintly alkaline.

less marked when the extract was boiled first, since then only a slight browning appeared. Young roots also turned black at the tips when allowed to remain twenty-four hours in an extract of infected soil from which all soil and fungus mycelium had been filtered off. In the control the root-tips remained unchanged and uninjured. In five similar experiments using a weak extract[1] of fungus sporophores instead of the soil extract the results were identical.

A similar extract of sporophores of *Agaricus campestris* discoloured and doubtless killed the young roots of grass, but the discolouration here differed from that produced by the extract of *Marasmius oreades*, in that it was a general discolouration, the whole root being blackened, more especially in the region of the stele as well as the root-tip. The discolouration was not so intense as that produced by the extract of *Marasmius oreades*.

These experiments, together with observations made on roots which have just been attacked, suggest that the fungus first excretes some toxic substance which kills the sensitive root and root-hairs, then penetrates and consumes the tissue of the root-apex, finally attacking the cortical tissue of the older parts of the root. The more copious branching which seems to accompany infected roots, is no doubt due to a constant effort on the part of the plant to make up for the continuous destruction of root-apices which goes on in the presence of the fungus.

6.—Proteolytic Enzymes.

Since a crop of grass is always more abundant and deeper in colour after the application of nitrogenous manure, the fungus sporophores and the soil containing mycelium were tested to see if perchance they contained any proteolytic enzymes, by the help of which they could easily assimilate nitrogenous compounds.

An extract of sporophores was obtained by pounding in a mortar 10 gms. of shredded sporophores with 20 cc. of water; this was left for twenty-four hours and strained and filtered before using.

The extract of infected soil was obtained by pounding up the soil with sufficient water to cover it, and after leaving for twenty-four hours, filtering before using. Toluol was used as an antiseptic, and the experiments were repeated several times.

In testing for peptase 0.5 gm. of vegetable fibrin was digested with 40 or 50 cc. of the extract of sporophores or of infected soil at a temperature of 40° C.; after twenty-four hours there was a great

[1] This extract was made by pounding up four or five grams of the sporophores with 100 cc. of water.

contrast between the size of the granules in the experiment tube and those in the control tubes of boiled extract; the diminution in size of the fibrin granules was more conspicuous in the case of the sporophore extract than with the soil extract.

In testing for ereptase 0.5 gm. of Witté peptone was digested with 45 cc. of sporophore extract. After twenty-four hours the liquid in the experiment tube gave a tryptophane reaction with Bromine water, whereas the control tube containing boiled extract gave no reaction.

These results showed quite clearly that an active peptonizing enzyme (peptase), which digests vegetable fibrin, and also a peptolytic enzyme (ereptase) which digests Witté peptone, were produced by the fungus.

These enzymes are no doubt the cause of the stimulating action of the fungus when it first attacks the grass plants, since by means of them it breaks up organic compounds of the soil which would otherwise be unavailable for the grass. Some of these no doubt the fungus itself assimilates, while others are absorbed by the grass roots.

7.—The Effect of the Mycelium on the Grass.

The amount of mycelium at first is not excessive, so that its destructive influence is more than compensated for by the extra supply of nitrogenous food material it renders available for the grass plant.

This stimulating effect of the fungus on the grass shows above ground in the darker colouration and improved growth of the grass just outside the dead grass ring. During the summer, autumn, and winter the mycelium increases in this outer zone until in early spring it becomes so copious that the grass can no longer withstand its attack, and so flags and finally dies. Then for three months or more a zone of dead grass is apparent, while crops of fungus sporophores appear on this zone at intervals for five or six months.

It has been mentioned that the fungus mycelium renders its substratum somewhat impervious to moisture; it might be thought that this aided the fungus in its attack upon the grass by enfeebling the latter and rendering it a more easy victim; but this does not appear to be the case, for prodding and watering a section of a fairy ring does not have the effect of delaying the death of the infected grass. Moreover, at the period when the grass is rapidly dying the soil has been found to be quite moist, and was known to have been so for weeks previously; also, the soil under the dark grass just within

the dead ring always contains very much less moisture than that of the field generally, and it cannot be said that lack of moisture enfeebles the plants of this zone.

After the fungus has destroyed the ring of grass, and even while still producing crops of sporophores, the grass on the ring appears to be recovering, but this recovery is due to the penetration of rhizomes from outside the dead grass ring. If the season is damp this takes place fairly rapidly, though excessive rainfall is unfavourable to the production of sporophores.

The luxuriance of the dark green grass which succeeds on the same zone, the dead grass of the previous year, may thus be said to be due partly to the activity of the fungus mycelium, which is still living but yet dying down since the substratum is almost unfit for its use, partly to the soil, from which for several months of the previous year no food substances were removed by grass, but especially to the nitrogenous manure contributed by the now dead mycelium, a manure which consists in part of the decaying mycelium itself and in part of easily assimilable products formed by it from dead roots in the soil.

8. -Intersecting Rings.

In pastures where fairy rings are numerous, instances often occur of one ring meeting and then gradually intersecting another (fig. C), in which case the rings are exterminated between the points of intersection so that in time one large ring is formed. Instances of this kind support the view that the fungus in some way renders the substratum on which it has been growing unfit for its further growth. Hence, the meeting of two rings must cause their extermination

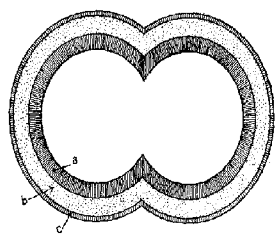


Fig. C.—Diagram showing the intersection of two rings. *a*. Inner dark green grass zone. *b*. Dead grass zone. *c*. Outer dark green grass zone.

between the places of interesection; also, the fact that the fairy ring extends as a ring and not as a disc, adds support to this hypothesis. This view receives further support from some culture experiments.

The culture medium was made either of a gelatine preparation (10 gms. gel., 3 gms. glucose, 2½ gms. peptone, 2½ gms. meat extract, and 100 cc. water), or of bread soaked with grass and horse-dung decoction, mixed with an equal volume of the gelatine preparation. This was placed in a shallow glass vessel in the centre of which was fixed a large watch glass. The latter contained equal parts of the culture medium used and a similar culture medium on which the fungus mycelium had been growing for twelve months and had become too exhausted for further growth to continue. This apparatus was placed in a glass jar and covered up with a glass disc. Every precaution was taken to obtain sterile apparatus and culture mediums. The cultures were infected by hyphae about 1.5 cms. long, taken from the middle of a stripe of a sporophore and placed so that half lay on the culture medium in the shallow glass vessel and the other half on the medium in the watch glass. Many of these cultures were utterly ruined by *Penicillium*, but several remained pure, and these answered expectations, for the growth of the mycelium over the medium in the watch glass was very poor and slow compared with that over the medium outside.

This seems to imply that some substance is excreted by the fungus which renders the substratum harmful to itself, rather than that it gradually uses up some essential food material, for in the watch glass there was at least half of the medium suitable for the growth of the fungus and there was no apparent reason for the fungus not flourishing on that.

It has been suggested that the fungus can only attack enfeebled grass plants, because it is well known that "Fairy Rings" of *Marasmius oreades* only grow on poor pastures. Now, if the outer zone of dark green grass were left out of consideration, this might be offered as an explanation of intersecting rings becoming exterminated between the places of intersection, since the mycelium of the touching dead grass zones would have to attack the vigorous plants of the inner dark green grass zones before being able to extend within the touching rings.

But it will be seen from figure C that before the mycelium of one ring can extend into another it would have to pass the stimulated plants of the outer dark green grass zone, and since these outer zones, as well as the other zones between the points of intersection of the rings, become gradually exterminated, there seems little doubt that

the extermination is caused by some toxic excretion of the mycelium of one ring rendering the substratum unfit for the growth of the mycelium from the outer ring.

During this investigation segments of "Fairy Rings" have disappeared if for any reason the ground in their immediate neighbourhood was much interfered with, as for instance by the planting of fruit trees in soil especially prepared for them. Under these circumstances the grass became very strong and vigorous near the trees, because the manuring of the soil stimulated it to increased growth and evidently brought about in some way the obliteration of parts of Fairy Rings.

This evidence supports the view that the grass if vigorous will resist infection by the fungus and offers some explanation of Fairy Rings usually only appearing on poor pastures.

It may perhaps be as well to point out that the manured grass just referred to resists infection because of its vigorous growth, but the luxuriant grass on the inner dark green grass zone resists infection because the mycelium growing in the same substratum is dying down owing to its own toxic excretions.

There are many instances known of one fairy ring growing within a much larger one, so that although soil in which mycelium has been growing will not allow of the growth of a second crop immediately following the first, in time it evidently recovers its normal state and the fungus once started continues its destructive work.

Many attempts have been made to start fairy rings on lawns and fields by using sods taken from rings of *Clitocybe gigantea* and *Marasmius oreades*, and by spores from the sporophores of these fungi, but without success. This has been a matter of surprise since two lawns laid with turf from a field containing rings of *Marasmius oreades* were kept under continuous observation, and although segments of rings appeared and grew for three years they did not flourish, and in the fourth summer, a very damp one, they never appeared at all.

It seems probable that sometimes the numerous fairy rings which occur in pastures have arisen from the breaking up of others; that is, the small segments of a large ring have formed the starting places of other rings, such as are represented in fig. D, and possibly this may be the reason why sections of rings are more frequent than whole rings (fig. D). For instance, it will be seen from the table of measurements given on page 118, that ring D, after being quite conspicuous in 1908 and 1909, disappeared in 1910, except for one round patch

fourteen inches in diameter; the ring did not appear again in 1911, but the patch increased in size apparently in nearly all directions.

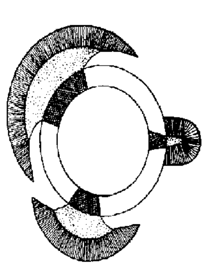


Fig. D.—The diagram represents the position of the dead grass zone of a ring in three successive years, and shows how segments of one ring might have the appearance, after several years, of belonging to entirely different rings; the patches of dead grass which were formed in the same year are shaded similarly.

Gilbert and Lawes[1] mention that rings on which few sporophores grow soon break up. This has also been observed during the present investigation, but the breaking up of rings is not directly connected with the absence of fruit bodies, except in so far as this implies a poor development of the fungus mycelium, and evidently unfavourable conditions for growth.

The mycelium of the rings is perennial, so the extension of a ring is not interfered with in the slightest degree if its sporophores are continually plucked as they appear, and the ring is thus kept free from any spore fall for a whole season. Fairy rings on lawns where constant cutting always interferes with the fruiting of the fungus, have been known to persist for years and cause considerable annoyance to owners uninterested in mycological studies.

III.—Fairy Rings formed by Clitocybe gigantea.

The Fairy Rings formed by the fungus *Clitocybe gigantea* (fig. E) agree in a general way with those just described. They appear about a fortnight or three weeks later, and their fruiting season is not so extended since their large sporophores (figs. F and G) are only to be found for about three or four weeks at the end of September and during October.

[1] Gilbert and Lawes, *l.c.*

The dead grass zone does not recover nearly so quickly from this fungus as from *Marasmius oreades,* in fact one ring in a field on the side of a hill at Sutton Coldfield, Warwickshire, was bare of grass for more than a whole year.

In the same neighbourhood there is a remarkably large oval ring incomplete only on the side where it meets a hedge. In 1910 the long diameter of this ring was about 168 feet and the narrow one

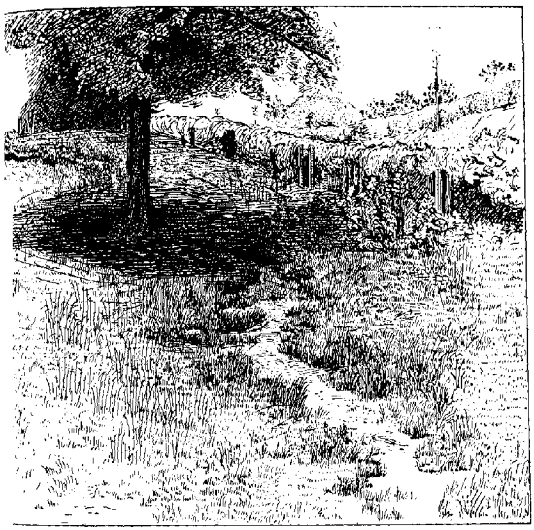


FIG. E.—The general appearance of part of a *Clitocybe gigantea* ring in 1911; the light streak in the field is due to the zone of dead grass.

84 feet. In 1908 the width of the dead grass zone measured in some parts fourteen inches, in others twenty-nine inches, and again thirty-one inches, but the general average lay somewhere between eighteen and twenty inches; the average did not increase during the next three years. Although the form of this ring is oval, the outline is extremely sinuous (Pl. vii); evidently the rate of growth of the fungus mycelium in this field is very variable.

This ring, at a distance of about half a mile when covered with dead grass, has the appearance of a well-trodden field footpath (fig. E). It has been known for at least seventeen years, and is said to have arisen from the intersection of two rings, although no trace of this is to be seen now.

Another very large, nearly perfect, circular ring, due also to *Clitocybe gigantea,* with a diameter of 48 feet, has shown two bare zones for two successive years—an inner one separated by a foot of grass from the usual outer one. There was also a slight trace of this inner bare ring in the large ring just referred to, but this showed only for a few weeks in the summer.

Fig. F.—Underside of the sporophore of *Clitocybe gigantea.* × $\frac{1}{8}$.

Very few sporophores have appeared on these rings except at long intervals. In September, 1906, there was an exceedingly fine show, and the rings were so conspicuous that the white line of sporophores (Pl. vii) formed a remarkable object even when seen a mile away; many of the sporophores were more than half a yard in diameter (figs. F and G); even the dark green grass zone within the dead ring can in summer and autumn be distinguished three-quarters of a mile away.

Fig. G.—Upper surface of the pilius of *Clitocybe gigantea*. $\times \frac{1}{8}$.

IV.—The Germination of the Spores of Fairy Ring Fungi.

1.—*Marasmius oreades*.

The spores of *Marasmius oreades* are white oval bodies, which germinate very slowly. They measure $6 \times 4\,\mu$ (Pl. v, fig. 3). They germinate after three days in a weak decoction of grass and in a nutrient solution of gelatine.[1] They will not germinate in tap water, or horse dung decoction, or in malt extract. Spores will germinate if kept dry for five or six days, but those six months old or more will not germinate.

It may be that these spores in order to germinate easily need to pass through the alimentary canal of some animal, such as a sheep, bird, or slug. Slugs (*Arion subfuscus*) have frequently been seen in the dead grass of a fairy ring, and many sporophores have been found partly devoured by slugs, but these creatures kept in captivity could never be induced to touch them.

The mycelium formed from the spores after one month breaks up into oidia, which germinate immediately and produce another mycelium consisting of a tangle of very fine hyphae, with frequent H-and clamp-connections.

[1] 10 gms. gelatine, 3 gms. glucose, $2\frac{1}{2}$ gms. peptone, $2\frac{1}{2}$ gms. meat extract, and 100 cc. water.

The mycelium from large cultures made on bread soaked with the gelatine nutrient solution, or malt extract, or on sterilized grass, showed a massing together of the hyphae into long branching strands or thin rhizomorphs similar to those which are to be seen in mycelium taken from infected soil (Pl. v, figs. 4 and 5).

None of these cultures ever produced sporophores, nor did the mycelium when buried in turf out in the open fields ever infect grass.

2.—*Clitocybe gigantea.*

The spores of *Clitocybe gigantea* are oval, and when seen in a mass have a very rich cream colour. They measure $6 \times 4\frac{1}{2}\ \mu$. They germinate within twenty-four hours in horse-dung decoction; they will also germinate in a strong decoction of grass, but then they require at least two days. After four days in horse-dung decoction all the spores were found to have germinated, while only 50 per cent. had germinated in the grass decoction. They will not germinate in tap water.

The germ tube arises at any position of the spore, and when only three or four times the length of the spore it begins to branch (Pl. v, figs. 8 and 9). Sometimes two germ tubes are produced. The mycelium produced from spores which have germinated in hanging drops after three weeks or a month begins to form large oidia (Pl. v, fig. 1), which germinate immediately (Pl. v, fig 2). Good cultures of mycelium were obtained upon bread soaked with horse-dung decoction and a few drops of grass decoction; this mycelium when examined, after growing for three months, bore a great resemblance to that of *Marasmius oreades* in having the hyphae of very narrow diameter, but there were no rhizomorphs. Occasionally enlargements of the hyphae, which might indicate the beginning of clamydospore formation, were met with (Pl. v, fig. 10); similar enlargements were found in mycelium permeating a sod taken from a fairy ring in December. No sporophores ever appeared on these cultures.

The sporophores of both *Marasmius oreades* and *Clitocybe gigantea* are edible.

V.—Summary.

1. *Marasmius oreades*, a common fairy ring fungus, is a parasite on grass.

2. It attacks young roots, kills them by means of some toxic secretion, and gradually destroys the whole plant except the steles.

3. The fungus is stimulating at first, and the grass assumes a darker colour owing to better nitrogenous nutrition due to the proteolytic enzymes of the fungus acting on the dead roots, hence there can be distinguished a zone of dark green grass outside the dead grass zone as well as inside that zone.

4. Infected soil is very impervious to moisture owing to air entangled within the meshes of the mycelium.

5. The fungus secretes some substance toxic to itself and so is not able to grow in the same soil three years in succession; during the second year the fungus dies off and the grass gains the upper hand and flourishes owing to the increased nitrogenous food available; hence, the "fairy ring" of rich luxuriant grass within the dead grass zone.

6. The secretion of this toxic substance accounts for the disappearance of rings between the places of intersection when fairy rings meet.

7. Fairy rings formed by the fungus *Clitocybe gigantea* agree in general with those formed by *Marasmius oreades*.

In conclusion, I wish to thank Professor West for the helpful criticism he has given me during the course of this work, and also Professor Buller, to whom I am indebted both for the subject of this investigation and for a number of suggestions made in the course of it.

EXPLANATION OF PLATES V, VI, AND VII.

Illustrating Dr. Jessie S. Bayliss' paper on "Observations on *Marasmius oreades* and *Clitocybe gigantea* as Parasitic Fungi causing 'Fairy Rings.'"

Plate V.

Fig. 1.—Hyphae of *Clitocybe gigantea* breaking up into oidia. × 800.

Fig. 2.—Oïdia of *Clitocybe gigantea* germinating. × 800.

Fig. 3.—Spores of *Marasmius oreades*, one is germinating. × 800.

Fig. 4.—Mycelium from a culture of *Marasmius oreades* showing massing hyphae (rhizomorphs). × 170.

Fig. 5.—Soil infected by *Marasmius oreades*. × 170.

Fig. 6.—A root tip of grass attacked by *Marasmius oreades*, showing the first stage. The shaded parts indicate a brown colouration caused by a toxic secretion of the fungus. × 800.

Fig. 7.—Mycelium of *Marasmius oreades* entering a leaf sheath. × 800.

Fig. 8.—Mycelium produced from the spore of *Clitocybe gigantea* after four days' germination. × 800.

Fig. 9.—Germinating spores of *Clitocybe gigantea*. × 800.

Fig. 10.—Structure probably representing the first stage in Chlamydospore formation of *Clitocybe gigantea*.

PLATE VI.

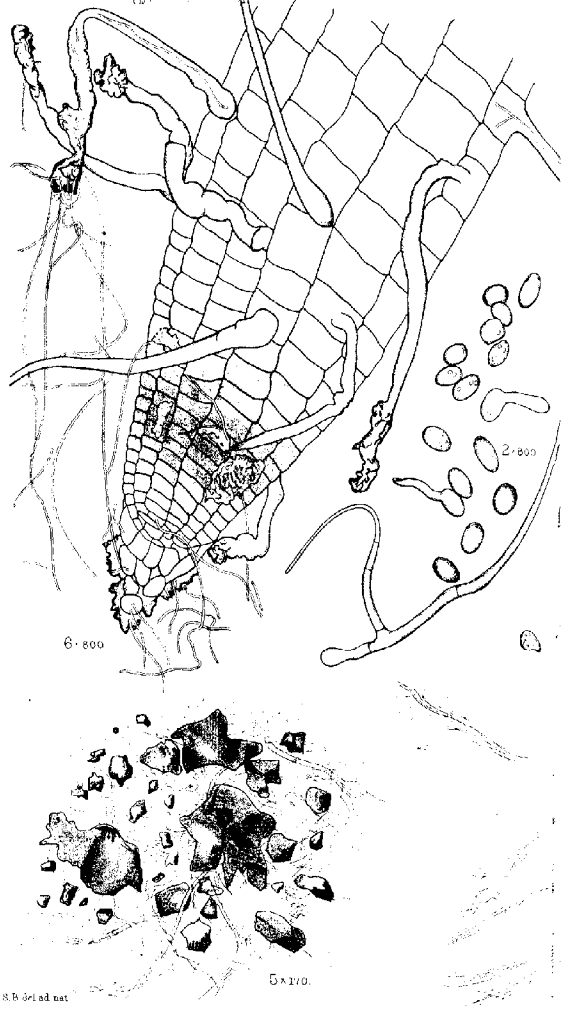
Fig. 11.—Root of grass with cortex partly consumed by *Marasmius oreades*. × 800.

Fig. 12.—Root of grass with nearly all the cortex consumed by *Marasmius oreades*.

Fig. 13.—Roots whose tips have turned black owing to the toxic action of a watery extract of soil infected by *Marasmius oreades*.

PLATE VII.

Fig. 14.—The general appearance of part of a *Clitocybe gigantea* ring in September, 1906. Many of the sporophores measured more than half a yard in diameter.



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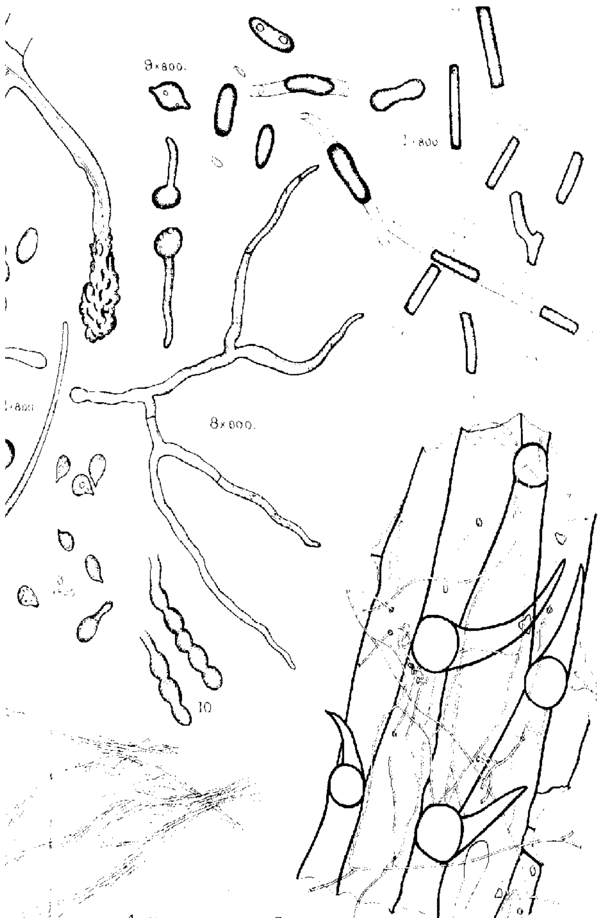
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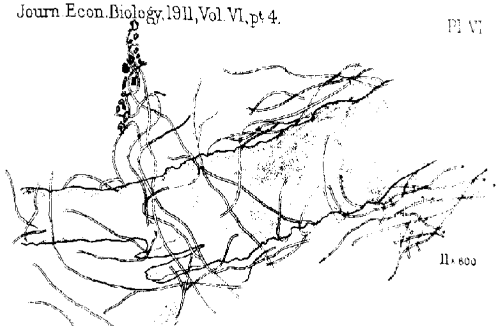

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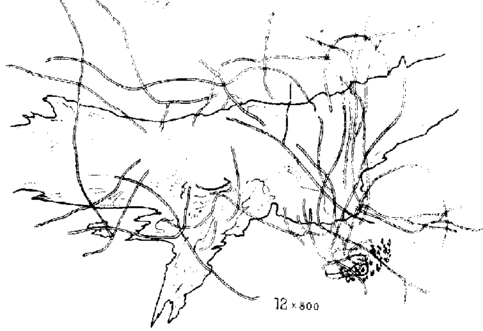

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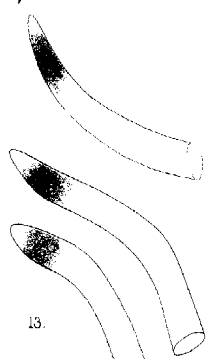

13.

THE OCCURRENCE OF *NECROBIA* AND *DERMESTES* IN COTTON BALES.

By

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Department of Economic Zoology, the University, Manchester.

WITH 4 FIGURES.

TOWARDS the latter end of May, 1910, some samples of cotton matted by the cocoons and infested with the active larvae and beetles of *Necrobia rufipes*, De Geer, were forwarded to the University with the information that all the bales of that portion of a consignment of Egyptian Cotton distributed to Belfast were affected in this manner to a depth of six or eight inches from the covering (fig. 1). From the carnivorous habits of this species, and from the absence of all but mature larvae, it was obvious that the insects were not feeding upon and multiplying within the cotton, but that they had merely invaded it for the purpose of pupation. The discovery that another portion of the same consignment was similarly attacked supported the idea that the bales had become contaminated while in the hold during the voyage from Alexandria, and all doubt upon this point was removed when further investigations revealed that the cargo of the vessel, besides cotton and sundry merchandise, consisted of skins, rags, bones, and dried blood. This year a very similar case of invasion of cotton bales by *Necrobia* larvae attracted attention, and again the source of infection proved to be the bones, dried blood, and such like materials carried by the steamer transporting the cotton.

That larvae of *Dermestes*, if afforded an opportunity, may in like manner seek to pupate in cotton was made evident by the receipt of a sample badly infested with mature larvae and pupae of *Dermestes vulpinus*, Fab., and *D. frischi*, Kug. It transpired that the larvae had penetrated beneath the surface of the bales just as in the previous cases. As this species pupates without spinning any cocoon, the cotton in this instance was not matted together, but on the other hand the workers handled it with great aversion and complained of the very objectionable smell. This particular consignment had been associated during transit from Alexandria with some 700 bags of bones.

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Extended enquiries failed to elicit any further instances of the occurrence of *Necrobia* or *Dermestes* under such circumstances as the foregoing. As similar cases may occur from time to time, and give

Fig. 1.—Cotton matted by the paperlike cocoons of *Necrobia rufipes*. Also showing beetles which have emerged. Natural size.

not a little anxiety to those concerned, it seems advisable to refer to the matter at greater length and to include some particulars as to the life-history and habits of these beetles.

Necrobia.

The genus *Necrobia* belongs to a family of beetles, the *Cleridae*, the members of which are carnivorous in the larval state, usually preying upon the larvae of various other insects. The three European species of *Necrobia*, small brightly coloured beetles, with

strongly clavate antennae and four-jointed tarsi (fig. 2), are very familiar to coleopterists, and as a result of commerce have become practically cosmopolitan.

In *Necrobia ruficollis*, Fab., which proved instrumental in saving the life of the celebrated Latreille during the French Revolution, a fact commemorated in the appellation *Necrobia*, the head and part of the elytra are shining blue, the base of the elytra, the thorax and the legs, bright red. The precise means of subsistence of the larva, usually found in association with skins, bones and other animal matter, is uncertain, as Perris (1) has shown that it may prey upon the blow-fly larvae present rather than upon the animal substances

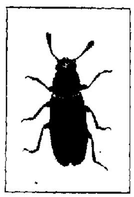

Fig. 2.—*Necrobia rufipes*. × 4.

themselves. He also made the interesting observation that the larvae pupated within the empty pupa cases of the blow-flies, constructing no cocoon with the exception of a little white material employed to close up the opening. Westwood's observations (2) suggest that it is capable of subsisting on the larva of *Dermestes*.

A couple of specimens of *N. ruficollis* were found in one of the samples of infested cotton, but since it is possible that they normally pupate within the cast skins or pupa cases of other insects it is unlikely that their larvae are of such importance in this connection as those of the next species.

The head, thorax, and elytra of *Necrobia rufipes*, De Geer (fig. 2), are entirely shining blue; the legs and base of antennae red. Length, one-sixth of an inch. The larva (fig. 3) is a slender active grub, with a small elongate brown head, brown prothorax, the other segments greyish white, with peculiar violet brown mottlings on the dorsal surface of each, and bearing thinly scattered setae. The last segment bears dorsally a strongly chitinised brown sclerite, which is

elevated into two short, blunt, hooklike processes. Pupation seems to always take place within a perfectly white cocoon of paperlike texture, and it is by adhering to this during its formation that the cotton becomes matted together.

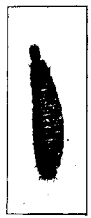

Fig. 3.—Larva of *Necrobia rufipes*. × 4.

There is no doubt that the larva can subsist entirely upon dead animal matter, for in America this species is known to dealers in dried meats as the Red-legged Ham Beetle or "paper worm," and its habits in this connection have been investigated by Dr. Howard (3). The larvae, after a rapid growth at the expense of the fatty tissues of the ham, "either gnaw into the muscle of the ham or occasionally eat into a neighbouring *beam*," there forming their paperlike cocoons. Usually found in the vicinity of skins, carcases, old bones and such other animal matter, it is just possible that in such situations this beetle may subsist by preference upon the other carnivorous larvae which feed on these substances.

Necrobia violacea, Linn., an entirely blue species, with dark legs, does not occur so commonly as the other two, but has a similar habitat. I did not at any time find specimens of this species in the cotton.

Dermestes.

Many members of the family *Dermestidae* enjoy wide notoriety in consequence of the frequent and severe depredations wrought upon furs and hides, food stuffs and fabrics by their voracious larvae. *Dermestes vulpinus*, Fab., one of the most destructive of these beetles, seems capable of subsisting in the larval state upon most animal substances, and a cargo of cork even has been destroyed by its agency. It is a dusky, oval insect, closely covered with white hairs on the ventral surface (fig. 4, *c*). The well known dark brown

hairy larva (fig 4, *a*), when fully grown, pupates within the last larval skin, which the perfectly white pupa (fig. 4, *b*) partially or entirely forsakes through a slit along the head and dorsal surface.

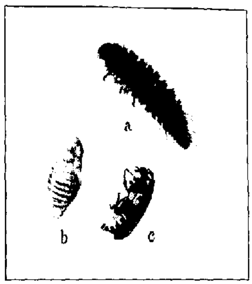

Fig. 4.—*Dermestes vulpinus.* *a.* Larva *b.* Pupa. *c.* Imago. All × 2.

Specimens of *Dermestes frischi*, Kug., a very closely allied, but less commonly occurring species, formed about a third of the adult individuals secured from the sample of infested cotton.

That cotton in the vicinity of material infested by *Necrobia* and *Dermestes* should be invaded by the fully grown larvae of these beetles is not surprising, as it is their habit to bury themselves away before pupating. The meshes of the jute or canvas wrapping of the bales can offer but slight impediment to them, as they are known to penetrate into woody and even, in the case of *Dermestes*, into bony substances. Moreover the bales are usually somewhat torn and gaping about the edges and elsewhere.

Though their presence may be disconcerting, these beetles are never likely to cause serious damage in such cases as the foregoing, as they do not appear to penetrate further than some seven or eight inches into the bale, but the sorting out of the infected material is of course a necessity. These consignments were always handled with a considerable amount of aversion by the workers, and where the *Dermestes* larvae were present they experienced a very objectionable smell. Hence it is clearly advisable to avoid the juxta-position,

during transit and storage, of cotton, and of skins, hides, dried blood, or other animal products capable of harbouring such insects as *Dermestes* and *Necrobia*.

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ON THE LOCOMOTION AND LENGTH OF LIFE OF THE YOUNG OF *PULVINARIA VITIS* VAR. *RIBESIAE*, SIGN.

By

WALTER E. COLLINGE, M.Sc., F.L.S., F.E.S.

In the June issue of the *Journal of Economic Entomology*,[1] Mr. H. J. Quayle has an interesting paper on locomotion of certain young scale insects. At the time of its publication I was carrying out experiments myself on the subject, and as some of these confirm Mr. Quayle's conclusions, and other interesting facts have been brought out, of economic importance, they are described here in detail.

The species experimented with was the White Woolly Currant Scale (*Pulvinaria vitis* var. *ribesiae*, Sign.). The life-history is well known, having been described in various works on economic entomology, and need not be entered into here.

My first experiment was made by placing six newly-hatched scales on three separate sheets of smooth white paper, each measuring 72 × 42 inches. Previous experiments had shown that the scales invariably travelled towards the light, the papers were therefore placed on the laboratory bench facing the window, in a temperature of 78° F. The young scales were placed at the side of the paper furtherest from the light, and the distance travelled was marked off each half hour for two hours, and then carefully measured.

The second experiment was a repetition of the first in a temperature of 82°, and a third was tried in 84°.

The results are tabulated below.

RATE OF TRAVEL ON SMOOTH PAPER.

Exp. No.	Date.	Time.	Temp.	Distance each ½ hour.	Total.
1a	June 19, 1911	10·30—12·30 p.m.	78° F.	20, 19, 20, 15	74
1b	„ 19, 1911	11·30—1·30 p.m.	78° F.	20, 20, 19, 16	75=75·1 inches
1c	„ 19, 1911	2—4 p.m.	78° F.	20, 21, 20, 16	77
2a	June 21, 1911	10·30—12·30 p.m.	82° F.	21, 19, 19, 17	76
2b	„ 21, 1911	11·30—1·30 p.m.	82° F.	22, 21, 18, 16	77=76·1 inches
2c	„ 21, 1911	2—4 p.m.	82° F.	20, 20, 19, 17	76
3a	June 28, 1911	10·30—12·30 p.m.	84° F.	24, 23, 22, 18	87
3b	„ 28, 1911	2—4 p.m.	84° F.	26, 24, 23, 20	93=91 inches
3c	„ 28, 1911	2—4 p.m.	84° F.	25, 24, 24, 20	93

[1] 1911, vol. iv, pp. 301-306.

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A further series of experiments were made, using a sheet of glass instead of the smooth paper. As the results were practically the same as those tabulated above, the actual figures are unnecessary.

Finally, three series in different temperatures were made on the laboratory bench. This has an oiled teak top, and the surface is, of course, considerably rougher than either the paper or glass.

The procedure adopted was similar to that recorded above, and the results obtained are interesting as the surface more nearly resembled the actual natural conditions than in the case of either the glass or the paper.

RATE OF TRAVEL ON TEAK BOARDS.

Exp. No.	Date.	Time.	Temp.	Distance each ½ hour.	Total.
4a	June 29, 1911	2—4 p.m.	78·5° F.	19, 18*	37
4b	„ 29, 1911	2—4 p.m.	78·5° F.	20, 18, 16, 12	66 = 51 inches
4c	„ 29, 1911	2—4 p.m.	78·5° F.	18, 18, 6, 8	50
5a	July 3, 1911	2·30—4·30 p.m.	83° F.	18, 17, 18, 10	63
5b	„ 3, 1911	2·30—4·30 p.m.	83° F.	18*	18 = 44·1 inches
5c	„ 3, 1911	2·30—4·30 p.m.	83° F.	16, 18, 18*	52
6a	July 12, 1911	2·30—4·30 p.m.	94° F.	18, 18, 16, 14	66
6b	„ 12, 1911	2·30—4·30 p.m.	94° F.	19, 6, 12, 10	47 = 55·2 inches
6c	„ 12, 1911	2·30—4·30 p.m.	94° F.	18, 5, 15, 16	54

* Specimens died.

In another case I placed some 60 to 70 newly-hatched Currant Scale on a sheet of white cardboard and exposed them to a temperature of 100° to 102° F.; they slowly dispersed over the board, and at the end of three and a half hours were fairly well scattered over an area of about two square feet. I then turned the board over. Examined four hours later nineteen of the scales had made their way on to the upper surface; sixteen hours later, quite fifty were on the upper surface exposed to a temperature of 102°, a few had fallen off the under surface and a few were dead.

Other experiments similar to those recorded by Mr. Quayle were tried, with very similar results, with this exception that I was unable to get a temperature any higher than 107° F.

Mr. Quayle[1] states that young examples of the Black Scale (*Saissetia oleae*, Bern.) died at a temperature of 84° F. "Experi-

[1] Journ. Econ. Entom., 1911, vol. iv, p. 305.

ments," he states, "relating to the effect of high temperature on young black scales showed that it is an important factor in the causes of death. Several hundred young black scales were liberated on white cardboard in the sun with a temperature of 94° to 100°; at the end of two hours they were unharmed by the heat. A similar experiment is recorded with a temperature of 106° to 110°. At 106° the scales were lively, but as the temperatures increased, they moved more slowly, and at 110° almost all movement ceased, although a two hours' exposure did not kill them.

Several hundred just emerged black scales liberated on soil with a temperature of 108° to 110° were active for about one hour, but at the end of that period some were dead, and at the end of one and a half hours nearly all had been killed. A check lot in the shade were not affected. A large number of young placed upon a board with a temperature of 118°, all died in five minutes. Scales exposed in sun on soil when temperature was 119° to 122° died within fifteen minutes. Under similar conditions, with the temperature of 130°, death resulted in five minutes. A check lot in the shade were not affected."

The distances travelled by *P. vitis* v. *ribesiae* are considerably shorter than those reported by Mr. Quayle, *e.g.*, on smooth paper; in two hours the Black Scale (*Saissetia oleae*, Bern.), at a temperature of 73.5° F., travelled a distance of 71.5 inches; at 80°, 76.5 inches; at 83°, 123.33 inches; and at 90°, 151.33 inches. The Red Scale (*Chrysomphalus aurantii*, Mask.) at 66° travelled 31.12 inches, and at 91°, 111 inches. The Purple Scale (*Lepidosaphes beckii*, Newm.) at 62°, 19.16 inches; at 68°, 32.87 inches; and at 89°, 111 inches.

Temperature undoubtedly plays a very important part in the rate and distance of travel.

On looking through a number of the leading works on the Coccidae I have been unable to find any reference as to the length of time the larvae will live when separated from their food plant. As the subject is one of considerable economic importance, the following observations may prove useful and interesting.

On July 6th I received a cutting from a Black Currant bush badly attacked with the White Woolly Currant Scale (*Pulvinaria vitis* var. *ribesiae*, Sign.). On the afternoon of the same day large numbers of the orange-red coloured larvae were noticed dispersing over the laboratory bench, some two hundred of which invaded a cardboard box.

On examining this box on July 15th quite half of the specimens were still alive and active. The dead specimens were taken out, and

the living ones allowed to remain. Examined again on July 18th seventy were still alive. Further examinations on the 20th resulted in finding twenty alive, on the 22nd twelve, on the 24th ten, and seven on the 25th, three of which died on the 26th, having existed for practically three weeks without any food and in a temperature of nearly 105° F., being on a bench in the window which received the full sunlight from 9 a.m. to 6 p.m.

Whether the larvae of other species are capable of existing for so long a period without food I cannot say, but the fact that an appreciable percentage of the original two hundred existed for a fortnight suggests great possibilities in the way of distribution of this insect.

The results obtained may be summarised as follows:—

1. On smooth white paper or glass surface the larva travelled nearly 8 feet in a period of two hours in a temperature between 78°-84° F.

2. On a teak boarded surface in the same length of time, at a slightly higher temperature the rate of progress was just over four feet in two hours.

3. In all cases the insects travelled in the direction of the light, and when placed in semi-darkness, they made their way towards the light.

4. The larvae continued to live in a temperature of up to 105° F., but higher than that the rate of mortality was great.

5. Three larvae lived in a temperature of 105°, without any food, for a period of 20 days.

REVIEWS.

Calman, W. T.—The Life of Crustacea. Pp. xvi + 289, 32 plts. and 85 figs. London: Methuen and Co., Ltd., 1911. Price 6s.

A work dealing in a semi-popular manner with the natural history of the Crustacea, fills a gap in such literature that has long been apparent.

All students of the Crustacea are now familiar with Dr. Calman's admirable volume on this Class in Lankester's *Treatise on Zoology*, but something less technical was desirable for another class of readers, that dwelt more particularly upon the habits, modes of life, and the various problems suggested by a study of these animals in relation to their environment.

Dr. Calman's volume fully meets this want, and the scope and method of treatment are both excellent. Treating first with the lobster as a type of the Class, the author passes on to a consideration of the classification and metamorphoses. This latter subject is very fully and clearly dealt with and well illustrated. Following this are chapters upon the crustacea of the seashore, of the deep sea, pelagic floating crustacea, the crustacea of fresh waters—an unusually interesting one. Subsequent chapters deal with the crustacea of the land, such as land crabs, land hermits, and wood-lice, crustacea as parasites and messmates, crustacea in relation to man, and crustacea of the past. A useful appendix on methods of collecting and preserving crustacea and some notes on books concludes a most fascinating volume.

Dr. Calman's work has none of the loose "popular" writing, common in so many recent natural history works, at the same time he avoids the more technical side, thereby making his book most interesting and readable.

The illustrations are all capital, the thirty-two half-tone plates being especially good.

The work is one we can heartily recommend, and we feel sure it will enlist a wide range of readers.

W. E. C.

Howard, L. O.—The House Fly—Disease Carrier. An account of its dangerous activities and of the means of destroying it. Pp. xix + 312, 1 plt. and 40 figs. New York: Frederick A. Stokes Company, 1911. Price $1.60 net.

Careful scientific investigations have now fully established the fact that the common house-fly is a dangerous pest which distributes the germs

of typhoid and other diseases. In this book the Chief of the U.S. Bureau of Entomology sets forth complete information about the fly.

No one is better qualified than Dr. Howard for such a task. As he points out, within the last two years, articles relating to the so-called house-fly in connection with its disease-carrying possibilities have been published literally by the thousand, and this interest, perhaps having its origin in the United States, has spread to nearly all parts of the civilized world, and yet in no one of these published articles is the whole story told. No one can find in condensed and convenient shape the general information he desires in regard to this insect.

The present work is not intended to be a scientific monograph; it is simply an attempt to tell in a simple and lucid manner what is known about the subjects indicated in the title.

After describing the nature of the common house-fly, its habits and methods of breeding, he proves his case against it as a carrier of disease, and goes on to what will be the most interesting section to most readers—that on remedies and preventive measures. He considers screening, fly traps and various poisons, repellants, and the treatment of breeding places. A special point is made of the possibilities of action by communities, with suggestions as to organization, publicity, interesting the children, and the work of Boards of Health.

The extermination of the house-fly is much to be desired as a means to public health, but it can only be accomplished by the widest publicity and a full understanding of the subject.

Dr. Howard has produced an admirable little book, full of interest and wise counsel. We should like to see a copy in the hands of every Public Health Department in the country, and in the hands of all intelligent citizens.

W. E. C.

Nuttall, G. H. F., and others.—Ticks: A Monograph of the Ixodoided. Pt. II. Pp. xix + 244, plts. iv-vii, and 202 text figs. Bibliography of the Ixodoidea. Pp. vi + 68. Cambridge: University Press, 1911. Price 12s. and 6s. net.

We welcome the second part of this valuable monograph. Part i, issued in 1908, dealt with the *Argasidae*, and the present part treats of Superfamily *Ixodoidea* and the Family *Ixodidae*.

The part is divided into two sections, the first of which gives a historical review relating to classification, synonymy and literature, and a series of exceedingly useful descriptions of the different generic characters, illustrated by figures, together with an explanation of the terms and signs used.

Section II. deals with the genus *Ixodes*, Latr. Here are most useful keys for the determination of the males, females, nymphs and larvae of the different species, followed by specific descriptions of valid species of the genus, and of their varieties and sub-species. It would be impossible to speak too highly of the care and thoroughness that has been bestowed upon this portion of the work. Nothing seems to have been lost sight of, and throughout all structural details are fully illustrated.

A list of the condemned and doubtful species of *Ixodes*, including their synonymy and literature, follows, and must prove of the greatest value to all students. It has undoubtedly entailed an enormous amount of work, in which careful discrimination and sound judgment have played an important part, as also the notes on doubtful species of *Ixodes*.

Dr. Nuttall contributes a series of most interesting notes on the biology of *Ixodes*, and there are reprints of two papers from the pages of *Parasitology*. Finally we have an index to the valid species of *Ixodes*, together with a list of the collections in which the types are to be found.

Professor Nuttall and his helpers are to be heartily congratulated on this splendid piece of work, which must long remain the standard work of these important and interesting animals.

The bibliography, containing 2,004 references, includes all the more important papers, although many references of an economic nature are omitted.

W. E. C.

Punnett, R. C.—Mendelism. Third ed. Pp. xiii + 176, 7 plts. and 35 text figs. London: Macmillan and Co., Ltd., 1911. Price 5s. net.

There are now quite a number of introductory books on Mendelism, but none have attained the success reached by that of Mr. Punnett's unpretentious work which appeared in 1905. A revised second edition followed in 1907, which has been twice reprinted in this country, and we now have a third edition, entirely rewritten, and much enlarged.

Whilst making no attempt to treat of the subject in the detail given in Mr. Bateson's admirable and indispensable *Principles*, it is comprehensive, concise, and wonderfully clear in method and style.

A third edition scarcely calls for review, although there is here much new matter in illustration of the growth of our ideas on this subject.

It is a work which in its present form will serve both as an introduction to a vast and fascinating subject, and for the ordinary reader a sufficing exposition.

The illustrations are all excellent and carefully chosen.

W. E. C.

Ross, E. H.—The Reduction of Domestic Mosquitoes. Pp. x + 114, 18 illustrations. London: John Murray, 1911. Price 5s. net.

The sub-title of this interesting work informs us that it is a series of instructions for the use of municipalities, town councils, health officers, sanitary inspectors, and residents in warm climates, and to all such we can unhesitatingly recommend it as a thoroughly practical handbook, full of sound common sense.

Dr. Ross sets forth in a most lucid and informing manner the importance of domestic mosquitoes, their life and habits, and the most practical manner of eradicating such pests.

The reduction of these disease carriers presents no difficulties, the cost is not great, and if properly carried out, it prevents certain diseases and interests the inhabitants and encourages them to notify sickness and the return of mosquitoes to the local authority.

The author's previous experience in Egypt eminently fit him for writing such a book, in which nothing of practical importance has been overlooked. There is an atmosphere of enthusiasm about it, and will go far in making converts and helpers.

W. E. C.

Spiller, G.—Papers on Inter-Racial Problems. Pp. xlvi + 485. London: P. S. King and Son, 1911.

This work includes the papers communicated to the First Universal Congress recently held at the University of London. Many of the papers do not come within the scope of this Journal, but there are many that have a distinct interest for students of eugenics, genetics, and anthropology. Of these we would mention Prof. V. Luschan's "Anthropological View of Race," "The Instability of Human Types," by Prof. Franz Boas, "Climatic Control of Skin-Colour," by Prof. Lionel W. Lyde, "The Effect of Racial Miscegenation," by Prof. Earl Finch.

There are many others that have a less bearing upon such subjects, or relate to them only in particular sections; all are, however, most interesting reading, and cannot fail to appeal to a large reading public.

There is a concluding and useful bibliography.

Theobald, Fred. V.—Novae Culicidae. Pt. i, pp. 35, 21 figs. Wye, 1911. Price 3s. 6d.

This publication, so the author informs us, will appear at irregular intervals, and be mainly devoted to the description of new *Culicidae* from Africa, Australia, Asia and Europe. The object is to have the new species described in a uniform series, instead of being scattered in journals and periodicals.

The part before us deals with a collection from Uganda, and contains a new *Stegomyia*, a new *Megaculex*, four new *Chrysoconops*, a new *Mimomyia*, and an undescribed *Harpagomyia*. The previously unknown male of *Culex cumminsii*, Theob., and the undescribed male of *Uranotaenia bimaculata*, Theob., are also described.

The work is beautifully printed and well illustrated.

W. E. C.

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PROCEEDINGS

OF THE

ASSOCIATION OF ECONOMIC BIOLOGISTS.

TENTH GENERAL MEETING, April 6th and 7th, 1911.

THURSDAY, APRIL 6th, 1911.

The Tenth General Meeting was held in the University of Birmingham.

The President, Professor Geo. H. Carpenter, occupied the chair, and there was a good attendance.

The minutes of the previous meeting were read, confirmed, and signed.

Mr. Richard S. Bagnall, F.E.S., was elected a member of the Association.

Prof. Geo. H. Carpenter communicated a paper on "Some Dipterous Larvae from the Turnip." Last year these caused considerable damage to crops near Dundalk, Ireland. They belonged to an apparently new species of gall-midge and to *Scaptomyza flaveola*. In connection with this species, several points of interest in the structure of the larvae were demonstrated by means of photographs and drawings shown in the lantern.

Mr. H. Maxwell-Lefroy, in a very interesting address, spoke on the training of economic entomologists. Not the least difficulty in making economic zoologists in England was the preponderance of the academic view, and the total absence of the economic view based on experience. He pointed out that, in addition to a training in zoology, botany, and chemistry, a course in agriculture should be taken, and a knowledge of field work in entomology was useful.

Mr. Walter E. Collinge read a paper on "House-flies and Public Health," in which it was pointed out that there was now no longer any doubt that cholera and typhoid fever were both spread by these insects, and that there was accumulating evidence that infantile diarrhœa, dysentery, and tuberculosis were also. Mr. Collinge con-

tended that a proper system of control and prevention were essential on the part of every corporate body having anything to do with the health of the general public. After briefly referring to the ordinances and regulations in force in other countries, he commented upon the inadequate conditions for the keeping of food in the modern dwelling house, and the necessary regulations for the disposal and storage of manure, &c. In concluding, he pointed out that it remained with the general public to educate the authorities in these and like matters if we have to remove from our midst a danger full of potentialities to ourselves and our children, and detrimental to the public at large.

An interesting discussion on the standardization of economic nomenclature was opened by Mr. H. Maxwell-Lefroy, and a committee consisting of Prof. Geo. H. Carpenter, Richard S. Bagnall, Dr. R. S. MacDougall, H. Maxwell-Lefroy, Prof. R. Newstead, and Walter E. Collinge (Hon. Sec.), was appointed to deal with the matter.

Dr. G. H. Pethybridge gave an account of some recent work on diseases of the potato in Ireland, where the potato crop is peculiarly liable to suffer. Great advances have been made in recent years in checking the ravages of different diseases, but there are still many that have not yielded to treatment. A considerable amount of attention has been given by the author to these, and the results are fully described and illustrated.

Mr. W. B. Grove described four little known British fungi, viz., *Mucor spinosus, Monilia lupuli,* n.sp., long known to brewers as occurring on spent hops, but hitherto undescribed. *Rhopalocystis nigra* was a new name proposed for *Aspergillus niger,* and *Hormodendron cladosporoides,* a species often confounded with *Cladosporium herbarum.*

Mr. Walter E. Collinge directed attention to the extremely serious nature of the plague of eelworms and white worms which are at present attacking different crops throughout the country, and to the scanty nature of our knowledge of their life-histories and bionomics.

Dr. J. H. Priestley initiated a discussion on the systematic recording of diseases of economic plants.

The occurrence of the beetle *Necrobia rufipes* in cotton bales formed the subject of an interesting communication by Mr. Joseph Mangan.

Mr. G. E. Johnson demonstrated some stages in the life of the nematode living in the nephridia of the earthworm.

The Association accepted the invitation of Prof. Carpenter to meet in Dublin in 1912 at a date to be fixed later.

ANNUAL MEETING, JULY 6th, 1911.

Held at the Rooms of the Linnean Society, London. Prof. Percy Groom occupied the chair.

The minutes of the previous meeting were read, confirmed, and signed.

In accordance with Law 12, the Council have nominated the following gentlemen as the Officers of the Association for the year 1911-12. No further nominations having been received, these were put to the meeting and declared elected.

President:

PROFESSOR GEO. H. CARPENTER, B.Sc., M.R.I.A., F.E.S.

Vice-Presidents:

PROFESSOR J. B. FARMER, M.A., D.Sc. (Oxon), F.R.S.
PROFESSOR SYDNEY J. HICKSON, M.A., D.Sc., F.R.S.
SIR PATRICK MANSON, K.C.M.G., LL.D., M.D., F.R.S.
PROFESSOR G. H. F. NUTTALL, M.A., M.D., Sc.D., F.R.S.
PROFESSOR E. B. POULTON, M.A., D.Sc., F.R.S.

Council:

PROFESSOR PERCY GROOM, M.A., D.Sc., F.L.S.
R. STEWART MACDOUGALL, M.A., D.Sc., F.R.S.E.
FRANCIS H. A. MARSHALL, M.A., D.Sc., F.R.S.E.
PROFESSOR ROBERT NEWSTEAD, M.Sc., A.L.S., F.E.S.
G. H. PETHYBRIDGE, B.Sc., Ph.D.
A. E. SHIPLEY, M.A., Hon. D.Sc., F.R.S.
FRASER STORY, F.R.S.E.
CECIL WARBURTON, M.A.

Hon. Treasurer:

R. T. LEIPER, D.Sc., M.B., Ch.B., F.Z.S.

Hon. Secretaries:

WALTER E. COLLINGE, M.Sc., F.L.S., F.E.S.
S. E. CHANDLER, D.Sc., F.L.S.

Mr. Collinge read the following Annual Report:-

SIXTH ANNUAL REPORT.

In presenting their Sixth Annual Report (covering the period, July, 1910, to July, 1911), your Council are pleased to record a year's steady progress and prosperity.

The total number of members of all classes on June 30th, 1911, was 104, namely:—

Honorary	8
Ordinary	89
Associate	7
	104

A successful and largely attended meeting was held at the University of Birmingham on April 6th and 7th, 1911.

On the invitation of the President it was decided to meet in Dublin in 1912.

The total receipts up to December 31st, 1910, amounted to £192 14s. 5d., whilst the total expenditure for the same period amounted to £59 13s. 4d., leaving a balance in the hands of the Hon. Treasurer of £133 1s. 1d.

There is also a small balance due for outstanding subscriptions.

Dr. Leiper presented the Treasurer's Statement attached.

On the motion of Prof. Boulger, seconded by Mr. Chittenden, the Report and Statement were approved of and passed.

It was decided to hold the Dublin Meeting during the Easter Vacation.

The best thanks of the Association to the Council of the Linnean Society for their kindness in granting the use of their rooms was moved by Prof. Boulger, and seconded by Mr. Collinge.

THE ASSOCIATION OF ECONOMIC BIOLOGISTS.

CASH ACCOUNT, 1910.

Receipts.	£	s.	d.	Expenditure.	£	s.	d.
To Balance in hand at Bankers, Dec. 31st, 1909	122	12	11	By Journal of Economic Biology ...	38	15	0
,, Receipts for 1910:—				,, Clerical Assistance	10	0	0
Members' Subscriptions (arrears) ...	2	2	0	,, Printing, Stationery, Postages, etc. ...	7	12	0
,, ,, for 1910 ...	59	6	6	,, Bank Charges		1	2
,, ,, in advance	3	16	0	,, Hire of Room		10	6
,, Entrance Fees ...	2	2	0	,, Secretarial Petty Expenses	2	14	8
Associates' Subscriptions ...	1	15	0		59	13	4
Sale of Proceedings during 1909-10	1	0	0	,, Balance at Bank, Dec. 31st, 1910 ...	133	1	1
	£192	14	5		£192	14	5

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